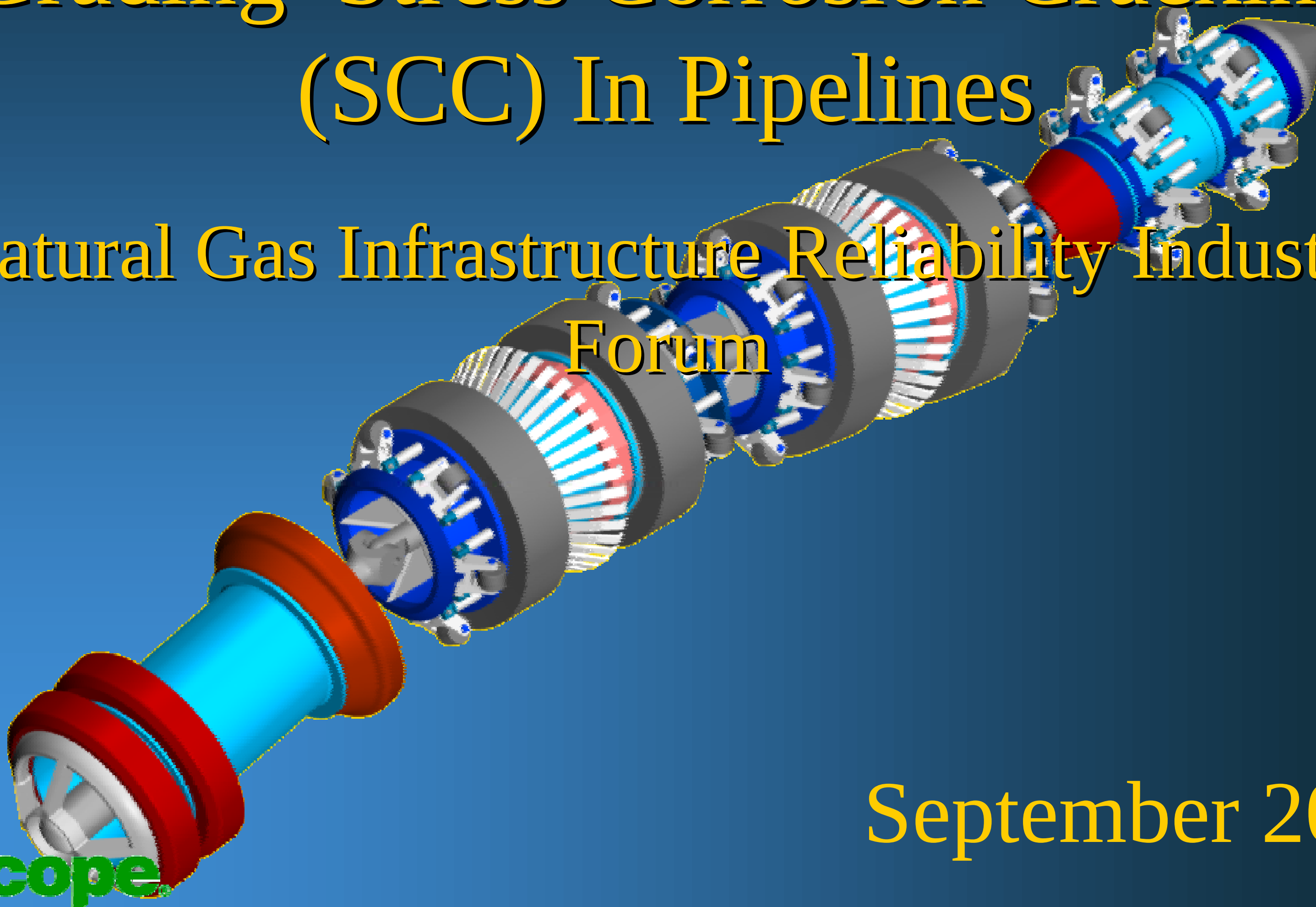
Development of an EMAT ILI System For Detection, Discrimination, and Grading Stress Corrosion Cracking (SCC) In Pipelines

Natural Gas Infrastructure Reliability Industry Forum



September 2002

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Development of an EMAT ILI System For SCC In Pipelines

Supported by: DOE NETL

Award: DE-FC26-01NT41154

To: Tuboscope Pipeline Services

Project Director: Jeffrey Aron

DOE Project Officer: Daniel Driscoll

DOE NETL Administration: Crystal Sharp & Kelly McDonald

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Summary

→ SCC Review

→ EMAT and Approach Review

→Lab Setup

→Lab Results

→Summary and Future Work

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DOE EMAT Project Goals

→Prototype ILI system to detect and grade Stress Corrosion Cracking (SCC) In Gas Pipelines

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What's the problem ?

Difficulties Posed By SCC

- →Axially oriented
- →Narrow (sometimes less open than .01")
- →Can occur in families of short cracks
- →Can be filled with corrosion materials
- →On outside of the pipe

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What's the problem ??

Difficulties Posed By Gas

→No contact gives poor to no acoustic coupling

Difficulties in the pipe

→Wear

→Must discriminate among other kinds of defects

→Voluminous data

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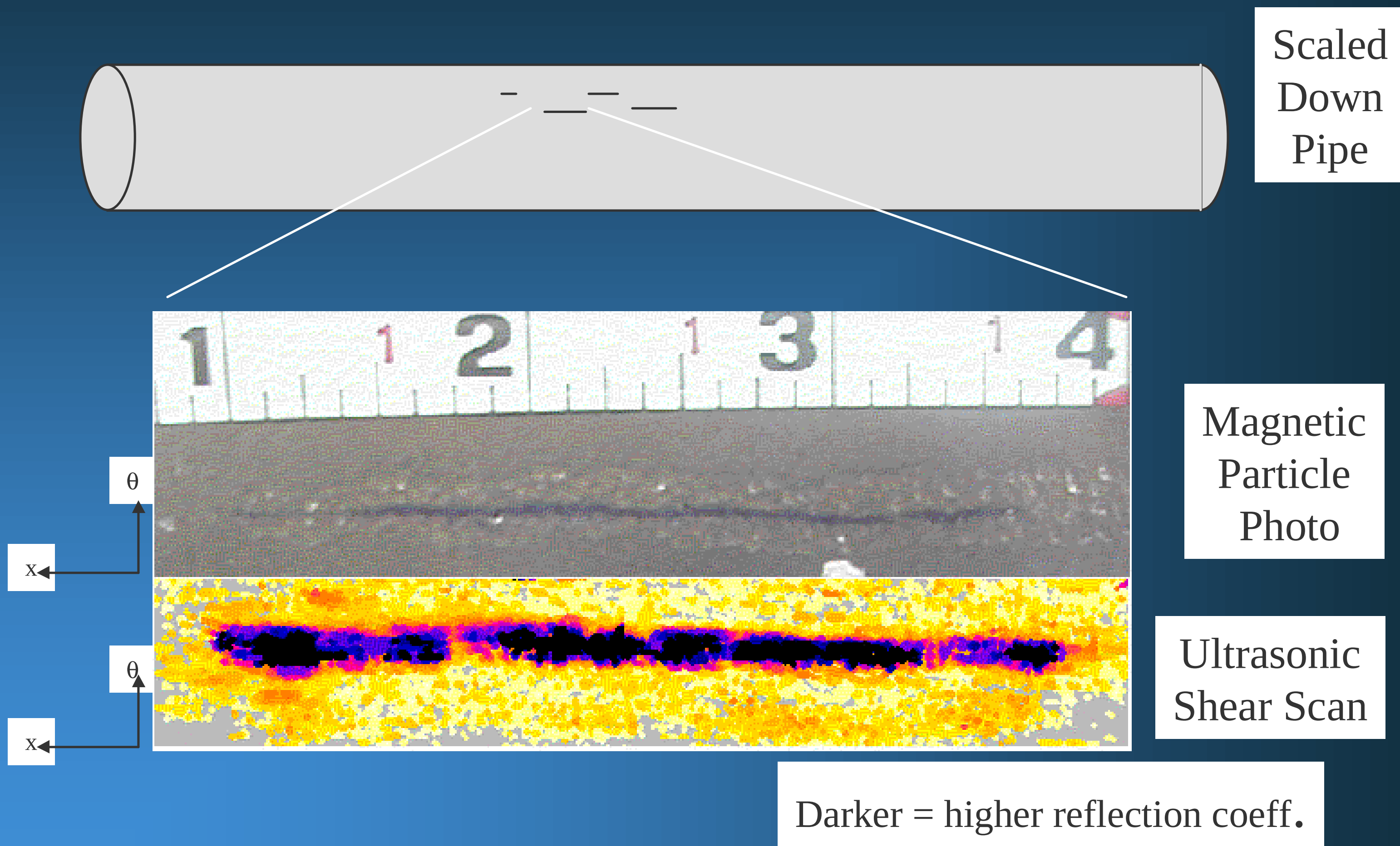
SCC Example 1

Axial and Narrow SCC



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SCC Example 2

Axial SCC Families

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Approach

Excite acoustic guided waves (nearly trapped modes)

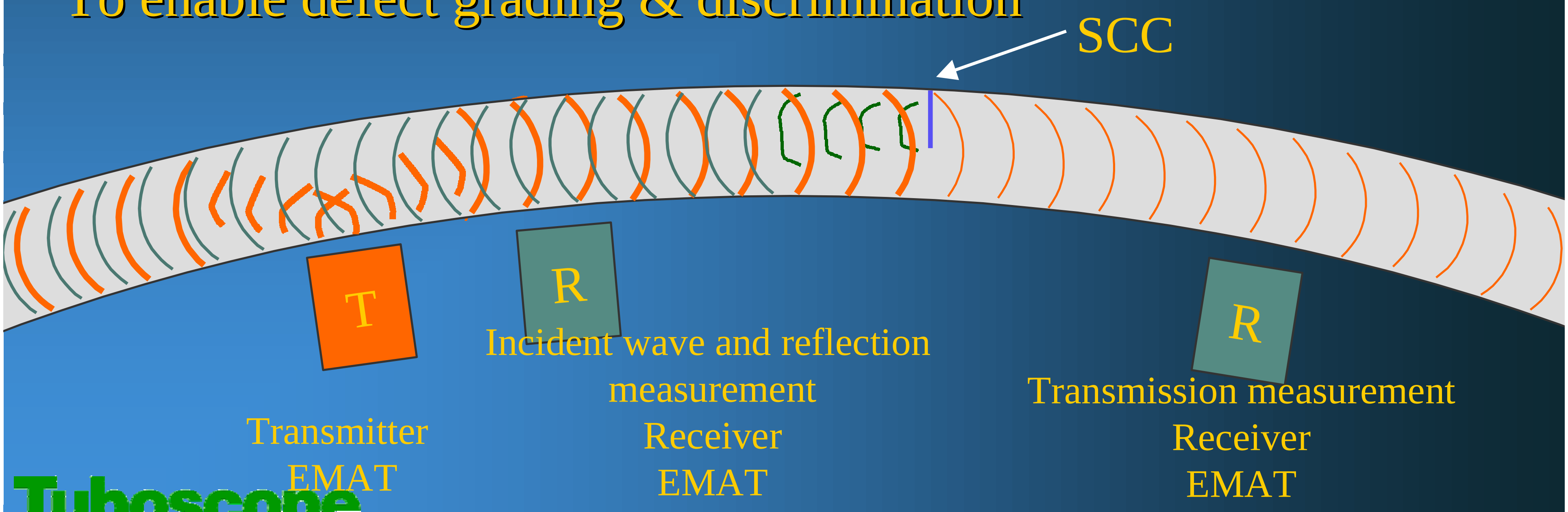
Measure their transmission and reflection amplitudes

Excite and receive with EMATs

Use different waves (modes), of which the

Energy concentration of each mode differs through the wall

To enable defect grading & discrimination



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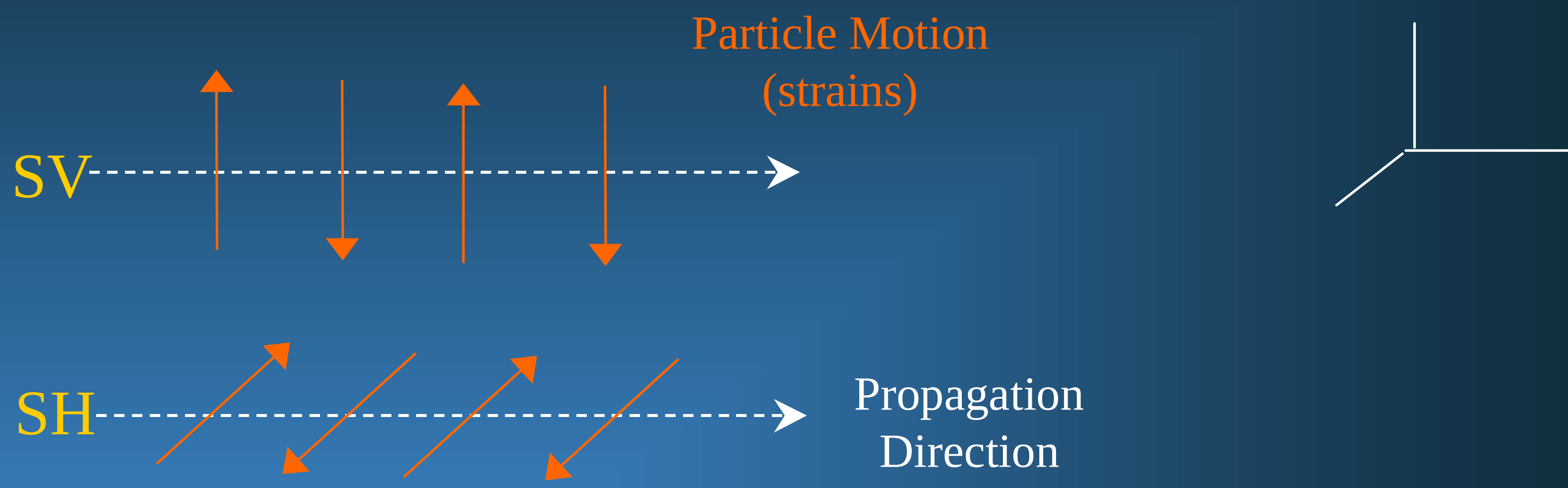
Two Kinds of Generic Modes: SH and SV Vibration Waves



- →Both have strong crack interactions
- →SH Advantages (in theory)
  - → Less attenuation due to in plane motion)
  - → Simple crack interactions; less conversion to other modes
  - → No or less dispersions

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EMAT :
Electro-Magnetic AcousticTransducer

- →Launches ultrasonic waves in metal
- →Doesn't need contact or fluid coupling but should be close to the conducting surface
- →Good for detecting/evaluating defects
  - Can launch shear waves
  - Easy to obtain circumferential directivity
- →A difficult technology, unlike piezo
  - Due to:
    - Low efficiency
    - High power requirements

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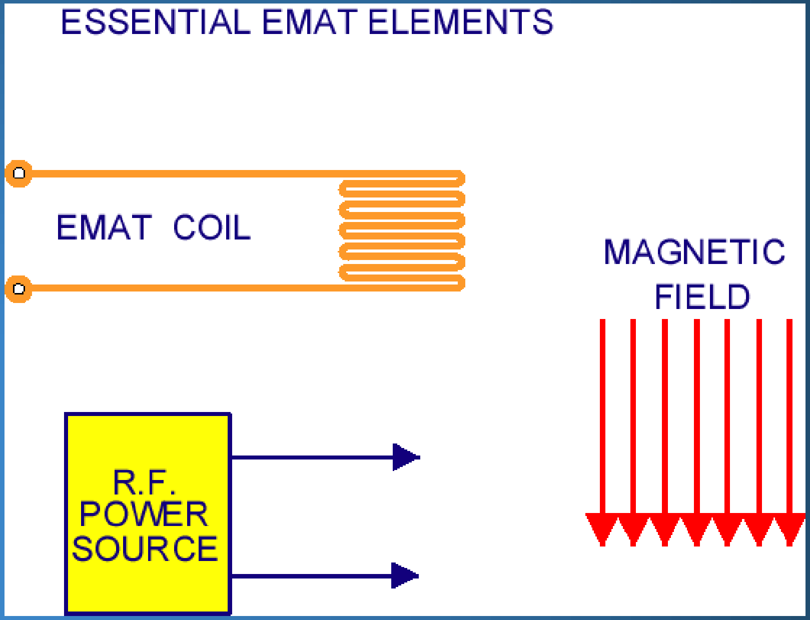
ElectroMagnetic Acoustic Transducer (EMAT)

- →EMAT requires
  - → Static magnetic bias field
  - → Coupling coil driven by
  - → AC (moderate freqs.) coil power for AC magnetic field
  - → Material excited msut be electrically conducting



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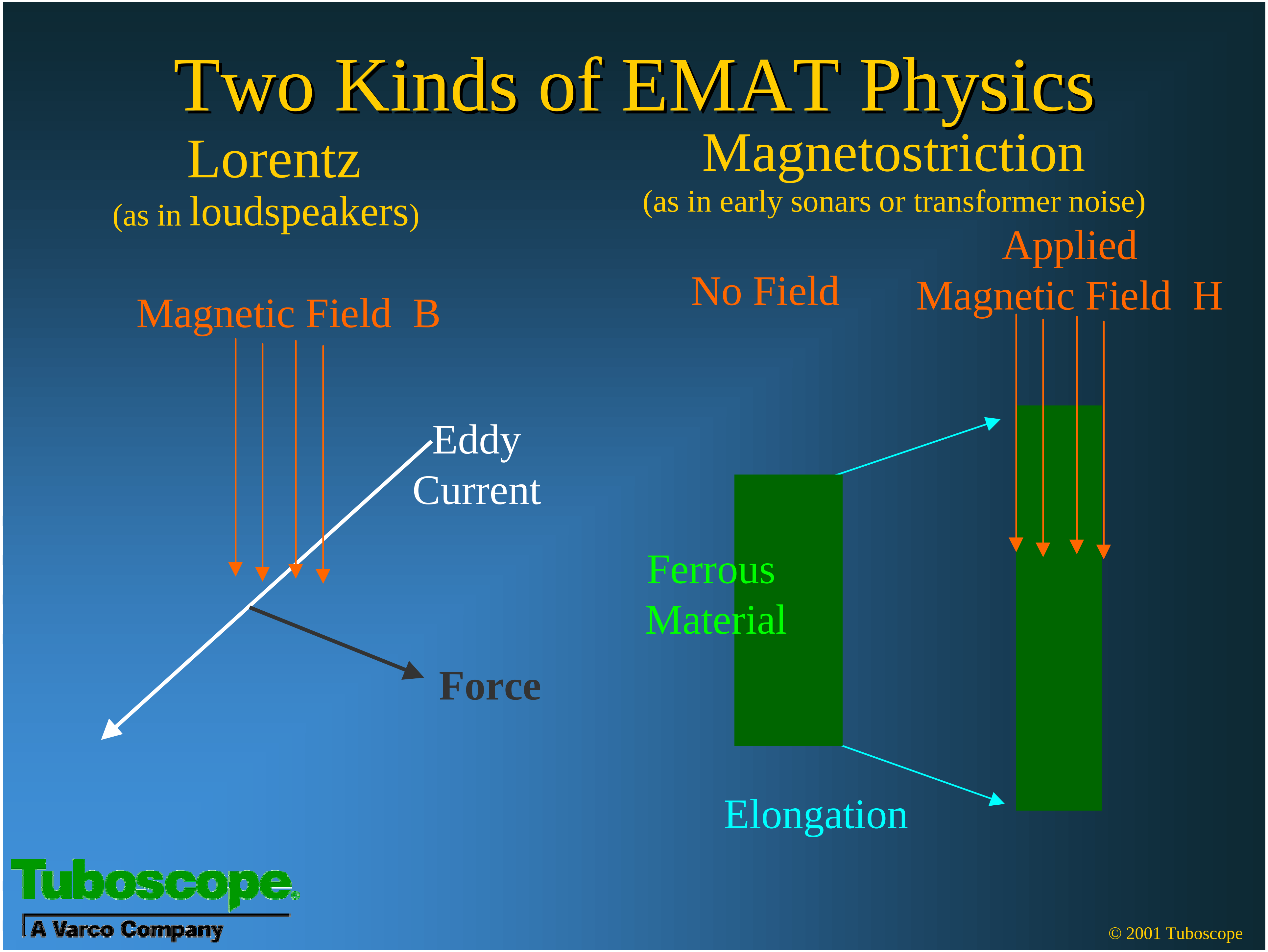
Two Kinds of EMAT Physics
Lorentz
(as in loudspeakers)
Magnetostriction
(as in early sonars or transformer noise)
Magnetic Field B
Eddy
Current
Force
No Field
Applied
Magnetic Field H
Ferrous
Material
Elongation
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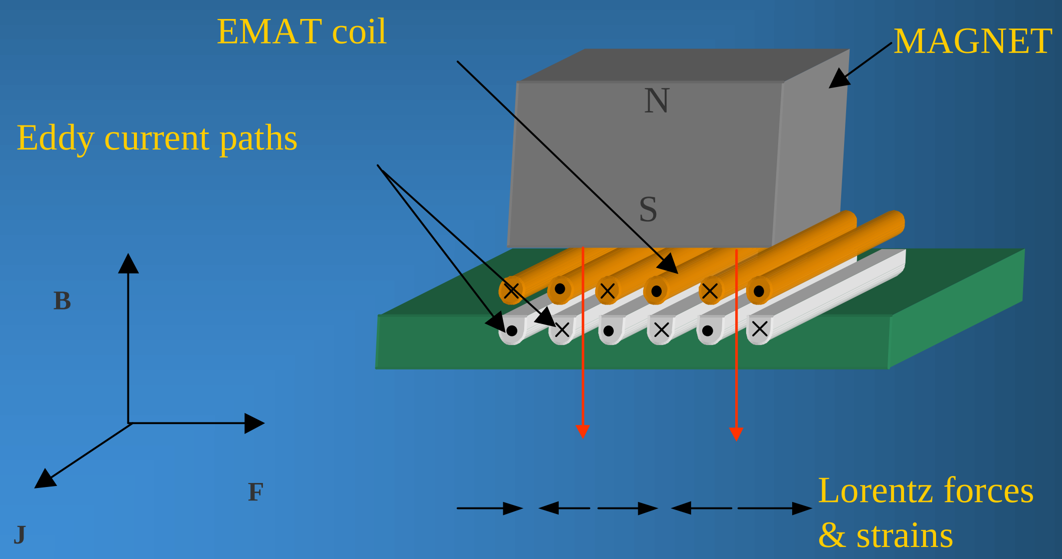
Lorentz EMAT

Field Perpendicular to Pipe

LORENTZ: (F=J X B)



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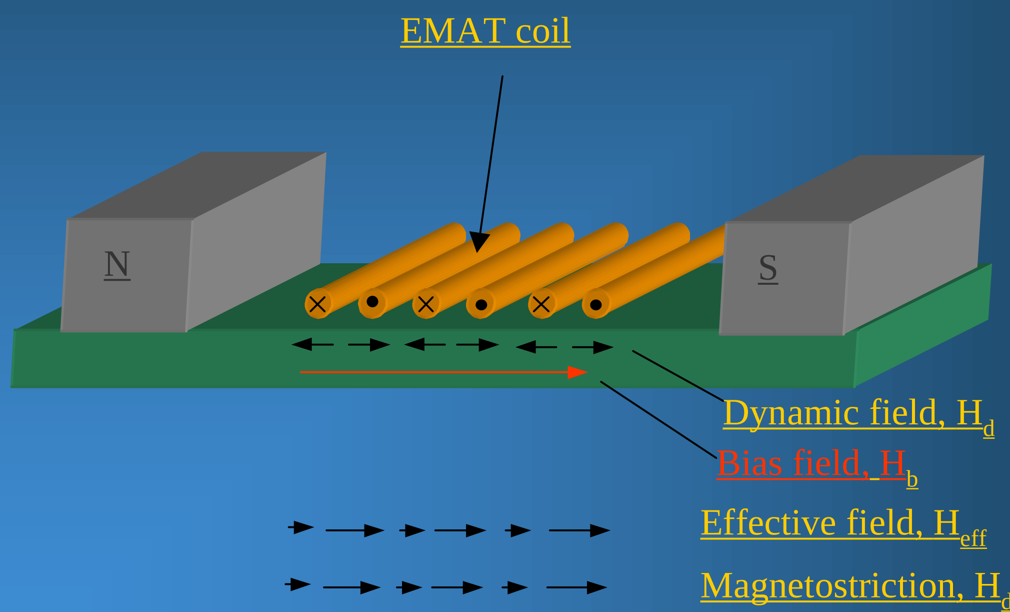
Magnetostrictive EMAT

Field Axial or Circumferential in Pipe Plane



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EMAT Challenges

- →Choice of Lorentz or Magnetostrictive
- →Choice of wave modes to probe with
  - →Frequency and transducer parameters
  - →Good SNR and crack sensitivity for pipes
  - →Attenuations & dispersion (from coatings)
- →Practical aspects for pigs
  - →Sensitivity to standoff and materials
  - →Wear & reliability
  - →Peak power requirements
  - →Speed effects

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DOE EMAT Project Goals

- →Phase 1
  - →Optimize & practicalize EMAT sensor/measurement with lab work
  - →Mouse and Mule pull tests & related systems development
- →Phase 2
  - →Prototype ILI system for SCC
  - →Test/ evaluate in a customer line

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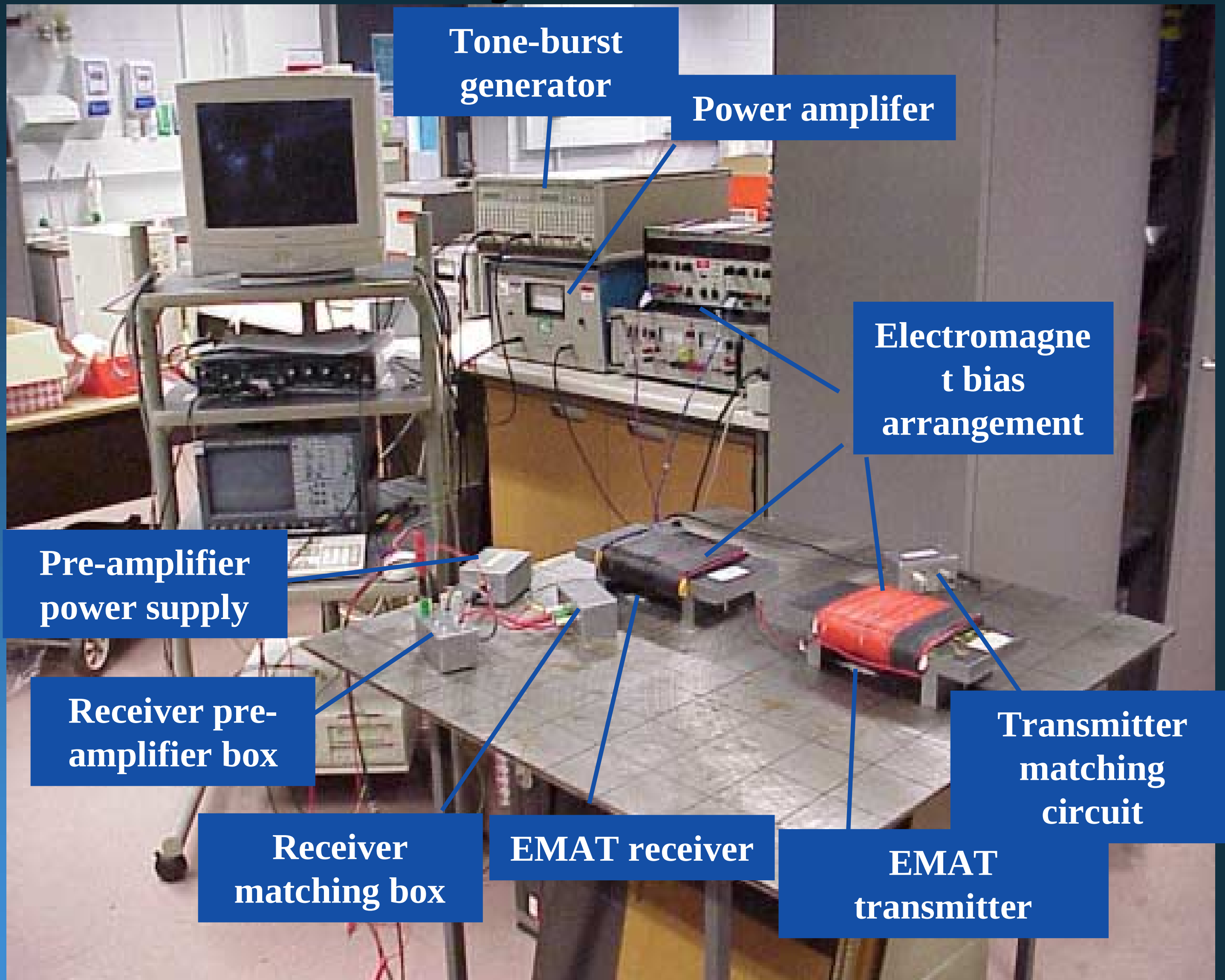
DOE Lab System



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Lab Systems Improvements

- Conformable, more efficient coils (in house)
- Efficient, low noise coupling and amplification
- SNRs: SV1=80 SH0=20
- Magnetic biasing and instrumentation now provide flexibility for investigations

Conformable EMAT Coils

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Lab Work

→Basic transducer parameters & sensitivity,

→SNR, Insertion Loss, Liftoff sensitivity, Beamwidth

→Man-made crack interactions

→Transmission and reflection

→SCC interactions

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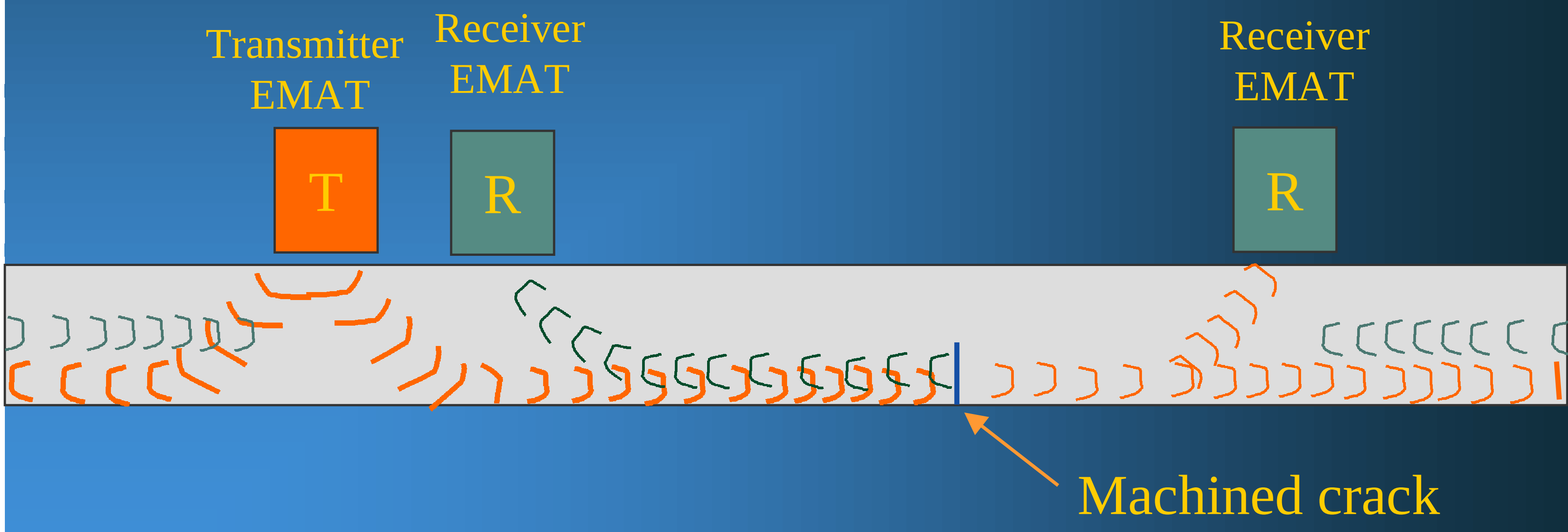
EMAT Lab Geometry
(PlanarTesting)

- → Transmit and receive EMATs
- → Transducer sensitivity evaluations
- → Crack reflections and transmission
- → Side reflections



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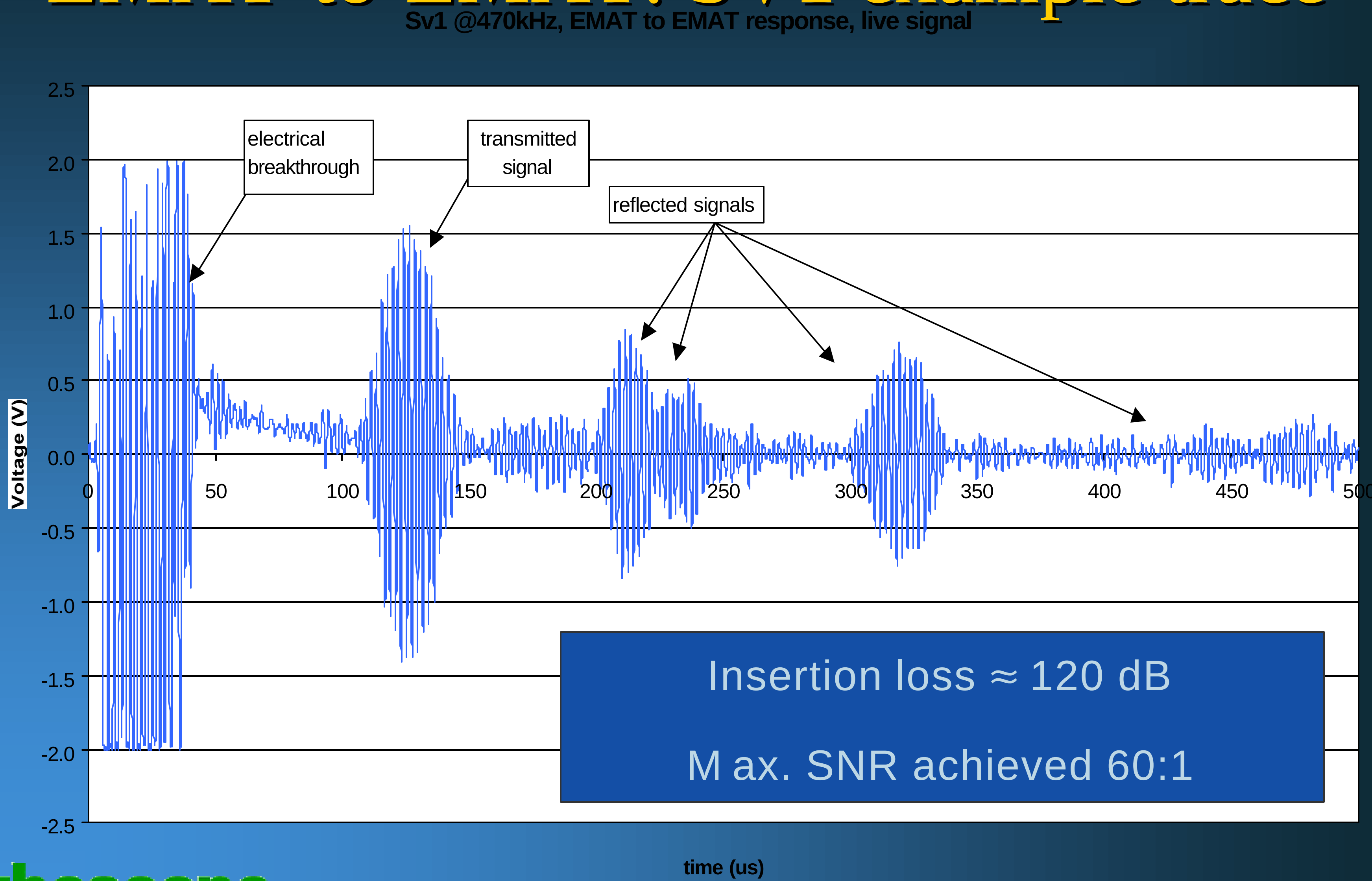
EMAT-to-EMAT: SV1 example trace



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Best Modes to Pursue at this time

- →Magnetostrictively generated
  - Magnetic bias separate from the coil
    - Implies lighter , simpler transducer head
  - Skin depth saturation > simpler bias schemes
  - SH > Axial magnetizer SV > Circumferential
- →SV1
  - Best SNR,
  - Demonstrated crack sensitivity
- →SH0
  - Low dispersion & attenuation,
  - Recommended crack for interaction
- →Other modes not as appealing
  - Too low or high in frequency or too long wavelength
  - May have too much attenuation or modal interferences

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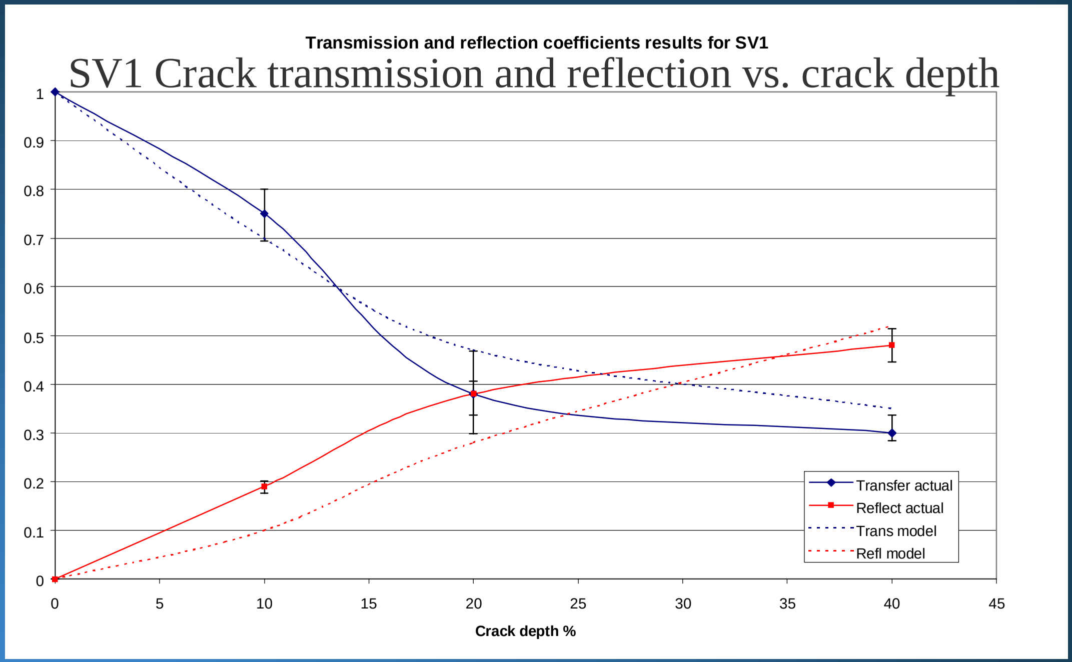
Man-made Crack Interactions

SV1

Actual > Prediction due to mode conversion

Effect OK but complicates interpretation



SH0

Good agreement between theory and measurement

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Modal measurements & sensitivities

(liftoff, tilt, beam width)

- →Has a wide beam (both advantage & disadvantage)

  Low spreading and low axial sampling

  Reduced short crack sensitivity and resolution,

- →No side lobes
- →Lift off sensitive

  1 or 2 mm of liftoff

- →Some tilt sensitivity

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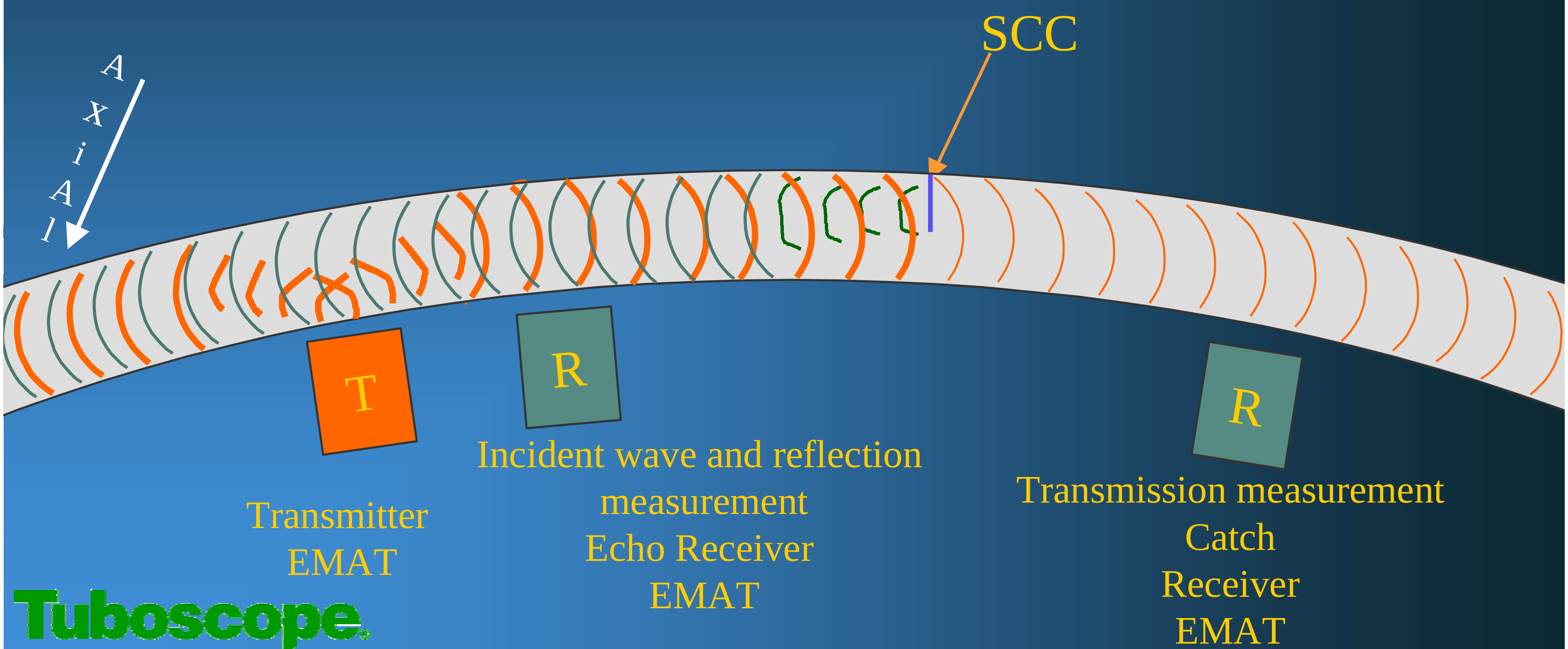
Possible EMAT Configuration



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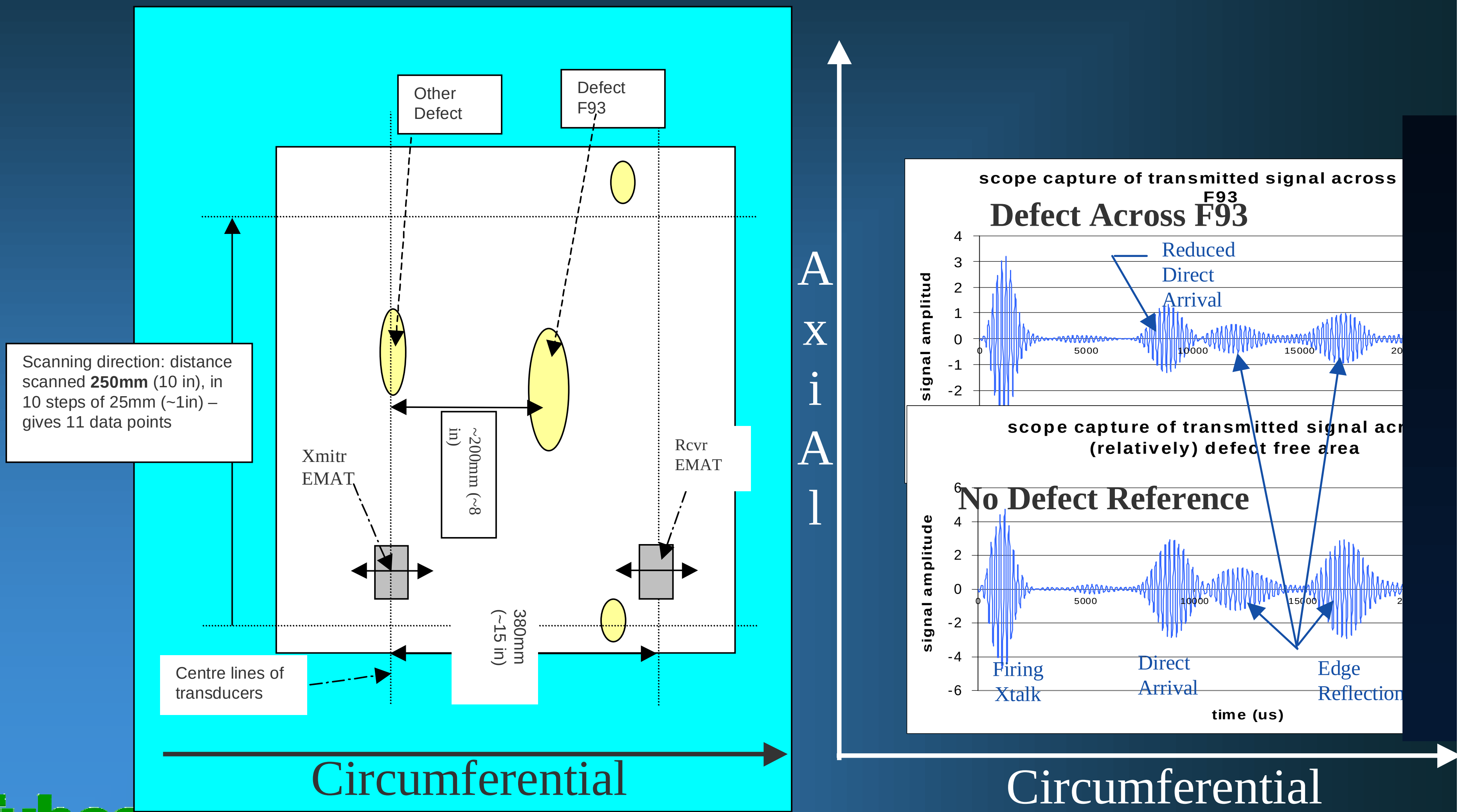
SCC Scan For SV1 Transmission



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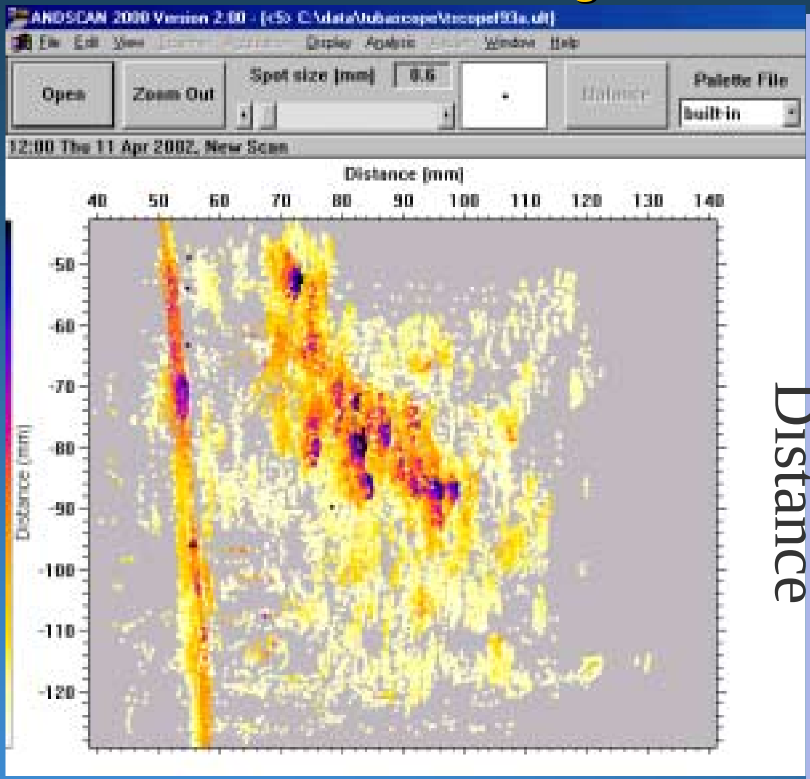
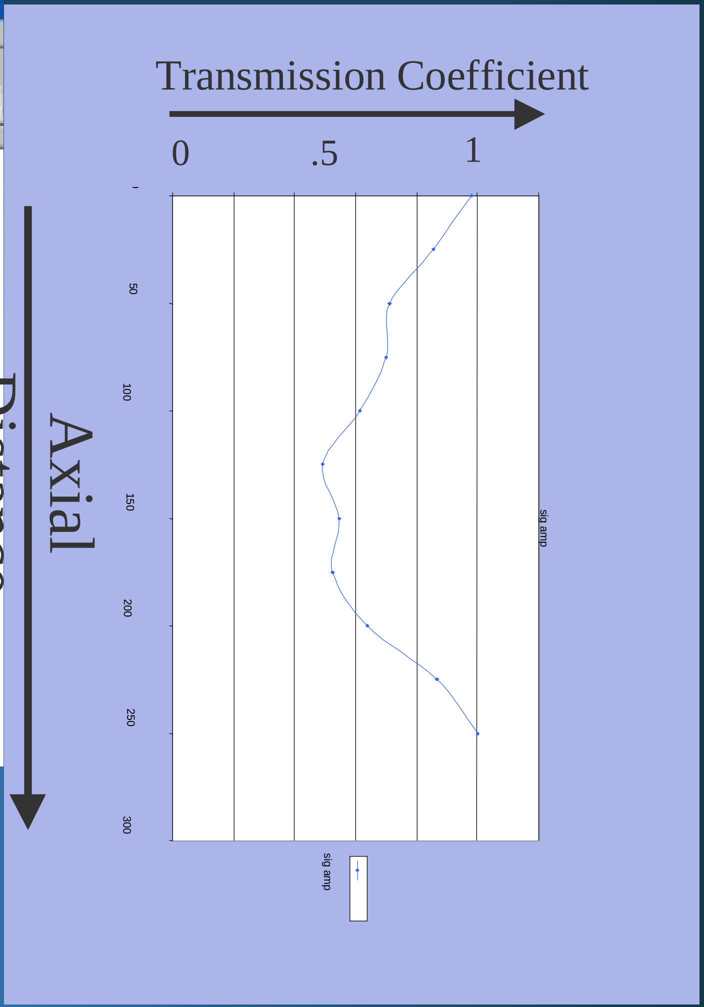
SCC Defect Scans

Dug Pipe Defect # 93

Conventional US acoustic ANDSCAN™ image

SV1 (470 kHz) Thru Transmission
Strong effects seen so far !!





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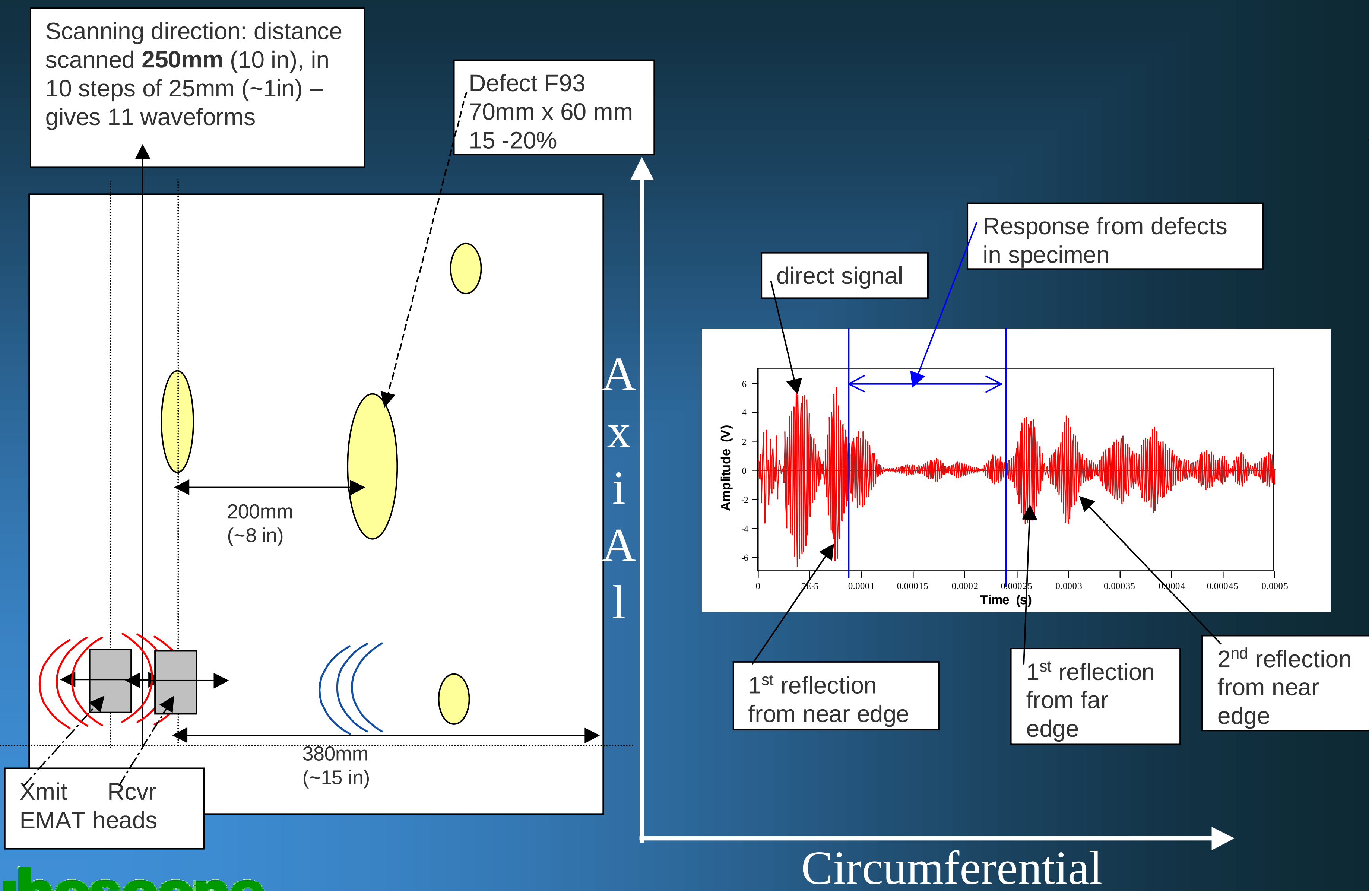
SCC Scan For SV1 Reflections



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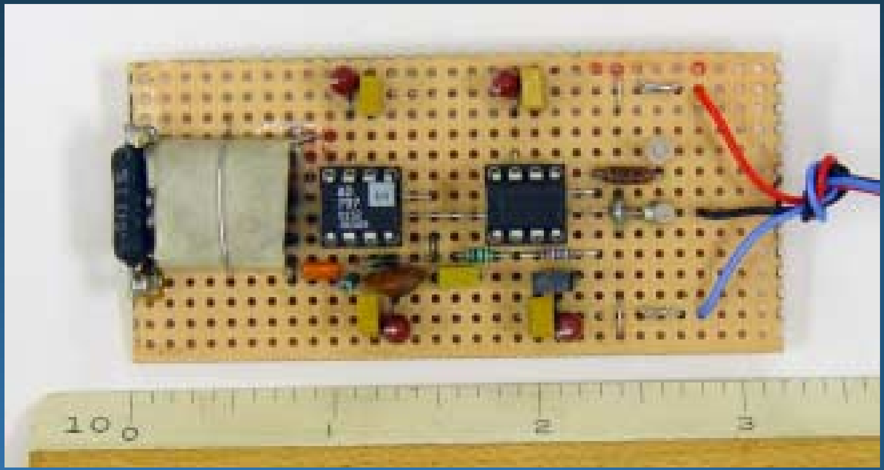
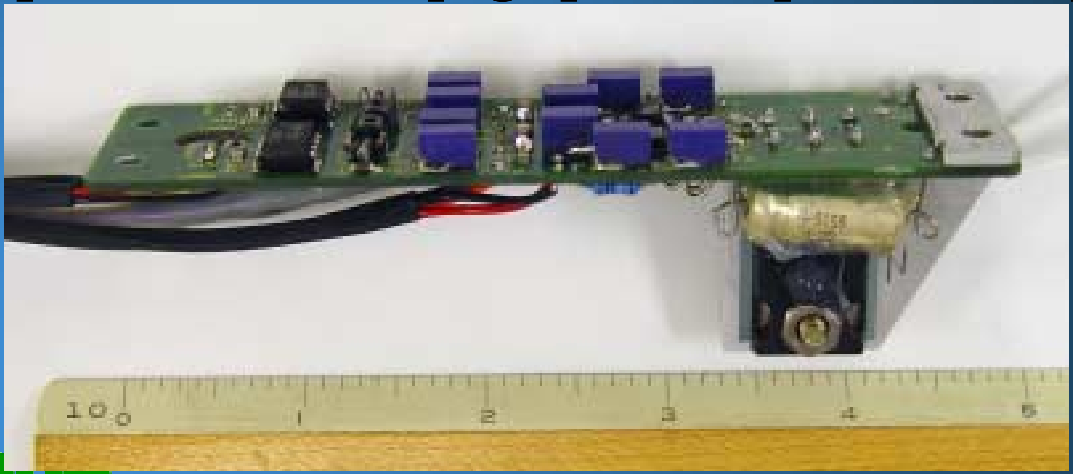
Pig Prototype Circuits

→Pig preamp compact prototypes

Low power, broad band, very low electronics only noise



→Compact/efficient pig, pulsed power amps (100 A ptp)



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Near Future EMAT Goals

- →Complete design/build for pull tests
  - Transducers, mounts, magnetic biasing
  - Drive/receive electronics
- →Run pull tests

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Thanks

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